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13. ABSTRACT (Maximum 200 Words)
The second year of this training/research project focused on ultrasound tomography system simulation, integrating, and the tomography image reconstruction. A micro-stepping motor has been purchased and integrated in the transmission ultrasound laboratory system (Imperium Acoustocam) and form a Transmission Ultrasound Computerized Tomography (TUCT) prototype system. The stepping motor is capable of rotating at a 1.8-degree per step with 200 steps per revolution up to a 1600 steps per revolution with 0.225 degrees resolution. Based on the prototype system, the first experiment of UTCT images has been performed using a silicone phantom. The image profiles were acquired by the Imperium Acoustocam. These image intensity profiles were then converted into ultrasound attenuation and used to reconstruct the ultrasound attenuation tomography images through filtered backprojection reconstruction algorithm. Since the CMOS acquisition is not perfectly linear with I100 chip, the newly developed I300 chip will be used to perform the study in the future study. In addition, a scattering component will be added in the filtering algorithm to compensate for the attenuation signal.

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1. INTRODUCTION

The second year of this training/research project focused on ultrasound tomography system simulation, integrating, and the tomography image reconstruction. A micro-stepping motor has been purchased and integrated in the transmission ultrasound laboratory system (Imperium Acoustocam) and form a Transmission Ultrasound Computerized Tomography (TUCT) prototype system. The stepping motor is capable of rotating at a 1.8-degree per step with 200 steps per revolution up to a 1600 steps per revolution with 0.225 degrees resolution. Based on the prototype system, the first experiment of UTCT images has been performed using a silicone phantom. The image profiles were acquired by the Imperium Acoustocam. These image intensity profiles were then converted into ultrasound attenuation and used to reconstruct the ultrasound attenuation tomography images through filtered backprojection reconstruction algorithm. The image intensity profiles, attenuation profiles and TUCT images of the testing phantom will be demonstrated in the following sections of this report. Since the CMOS acquisition is not perfectly linear with I100 chip, the newly developed I300 chip will be used to perform the study in the future study. In addition, a scattering component will be added in the filtering algorithm to compensate for the attenuation signal.

2. RESEARCH ACTIVITIES

2.1 System calibration and synchronization of the stepping motor with PC

In our laboratory, located in the Georgetown University Medical Center (GUMC), the TUCT system consists of two sources of equipment: an transmission ultrasound prototype (Acoustocam by Imperium Inc. - Silver Spring, MD) and an stepping motor system (MS-1 by Stepperworld - Los Angels, CA). The Acoustocam has several major components: (1) A 5MHz ultrasound transducer and generator, (2) a compound acoustic lens, (3) a sensing CMOS array, and (4) two display monitors. The stepping motor system consists of a micro-stepping motor and a controller with power supply. The assembly of the two modules for the ultrasound tomography is shown in Figure 1 and Figure 3. The imaging system must be operated in Windows NT environment but the micro-stepping controller must be operated in Windows 95, 98 or ME environment. In order to solve this problem, a laptop was used with Windows ME to control the stepping motor and the control panel is shown in Figure 2. This stepping motor has several settings for the angle increment: full-step (1.8-degree), half-step (0.9-degree), quarter-step (0.45-degree) and 1/8 step (0.225-degree) for the control of the operation.

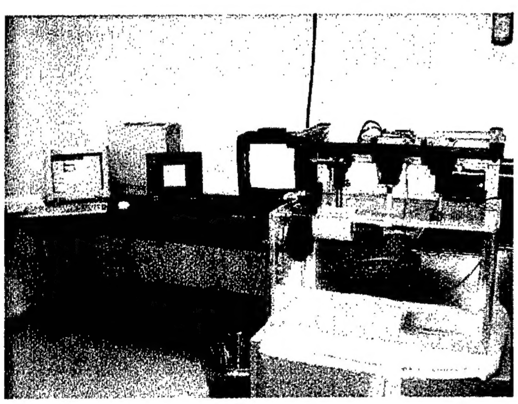


Figure 1. Overall system configuration

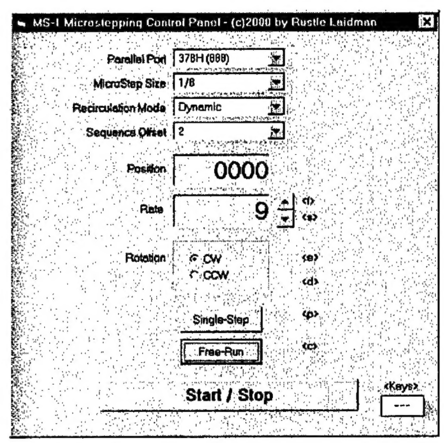


Figure 2. Micro-stepping control panel

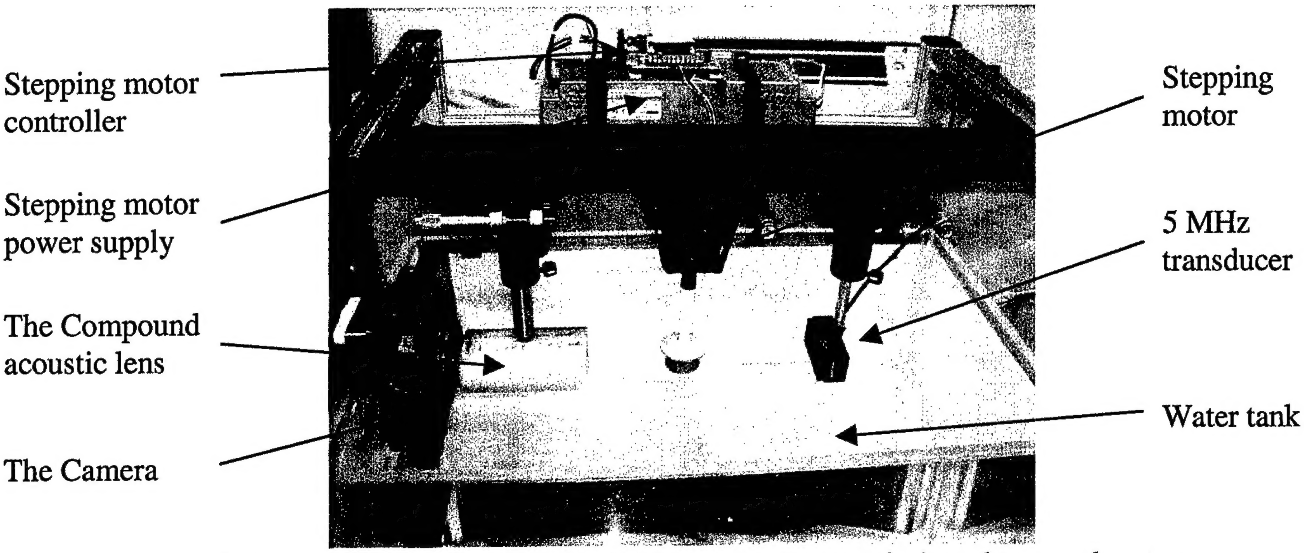
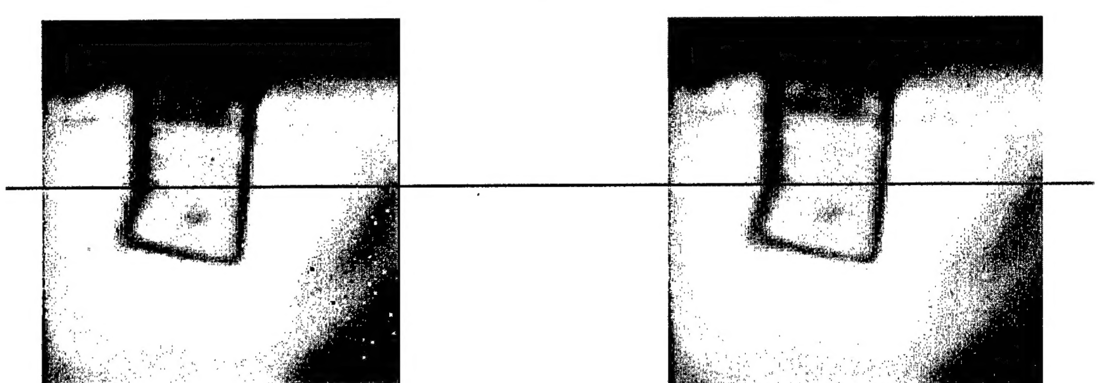


Figure 3. System components of the prototype transmission ultrasound system.

2.2 Development for the TUCT Prototype

A silicone phantom was made and was used for the first experiment. The phantom was mounted on the platform of the rotating rod and was immersed in the water. The stepping motor was then operated at ¼ step to provide the 0.45-degree increment of the rotation in the experiment. A total of 400 projections of the target were generated for 180 degrees rotation. The TUCT prototype collected the projection images from the CMOS sensing array. With these 400 projection images, we sample a single data profile from all projection views to form a *sinogram*. Each sinogram contains the same slice of the whole target at different angles. Hence we reconstructed an image of the target at corresponding slice based on the sinogram.

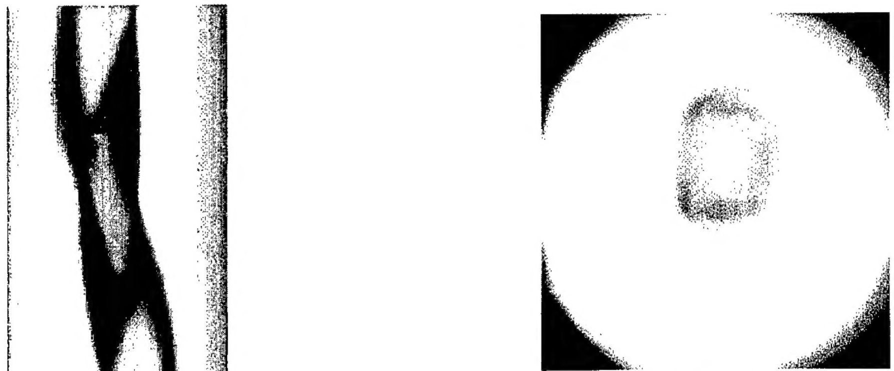
For example, the red line in Figure 4(a) represents the desired slice that we would like to reconstruct form the projections. First, the bilinear interpolation method was employed to remove the inactive pixels as shown in Figure 4(b). Then, the line profiles from the 400 projection images were sampled to form an ultrasound intensity sinogram as shown in Figure 5 (a). And its corresponding ultrasound attenuation sinogram is shown Figure 6(a). By applying the parallel-beam backprojection method, the result intensity and attenuation images are shown in Figure 5. (b) and Figure 6(b), respectively.



(a) Original projection image

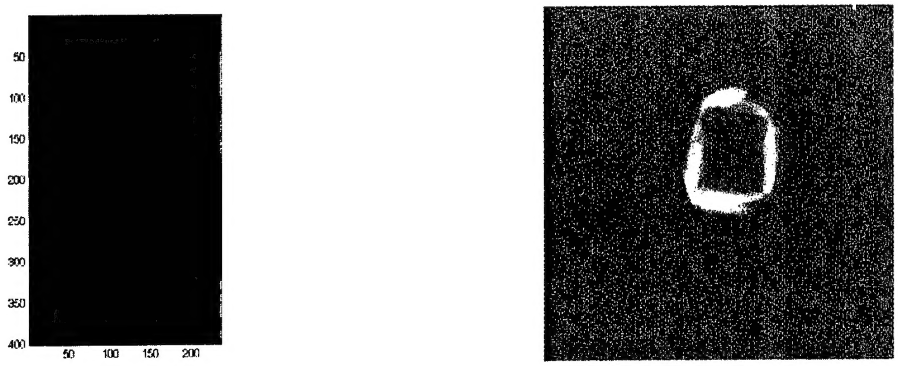
(b) After fixing inactive pixel

Figure 4. One of the projection images of the phantom



(a) Original sinogram (b) Result image

Figure 5. (a) The sinogram of the red line (b) The reconstructed result



(a) Extraction of the attenuation information (b) Ultrasound attenuation image without post-processing

Figure 6. (a) The sinogram of the red line profile. (b) The reconstructed result.

2.2 A Brief Theoretical Background of the Ultrasound Tomography

Let us assume that the original ultrasound intensity, I_o, is attenuated while the energy is passing through the material with a distance, z.

$$I = I_0 \exp[-\int_\theta \alpha_z dz] \quad \ldots (1)$$

where I = Intensity at depth z

I_0 = Intensity at the source

α_z = Attenuation coefficient

In this experiment, the distance of the transducer to the CMOS sensing array is fixed. Thus, we can extract the attenuation information by the following equation:

$$\int_\theta \alpha_z dz = \log\left(\frac{I_0(x,y)}{I(x,y)}\right) \quad \ldots (2)$$

The value on the each pixel of the attenuation sinogram, converted from intensity sinogram using eq. (2), represents the line integral of the ultrasound transmission. The filter backprojection was then used to generate the attenuation image α_z(x,y). This is demonstrated in the Figure 6(a) and 6(b). Figure 5(b), however, it does not have a physical meaning.

KEY RESEARCH ACCOMPLISHMENTS:

- Integrating an Acoustocam and a micro-stepping motor system to from a TUCT prototype system.

  A micro-stepping motor has been integrated a transmission ultrasound system to from a TUCT system that can generate ultrasound projection image at any angle.

- Test of the laboratory TUCT system: altered electronic component, designed phantoms and evaluated the laboratory system.

  Successfully getting prototype ultrasound computerized tomography images with a silicone phantom.

REPORTABLE OUTCOMES:

- Poster presentation in the U.S. Army Medical Research and Materiel Command's (USAMRMC) Era of Hope 2002 DoD Breast Cancer Research Program Meeting in Orlando, Florida, September 25~28, 2002.

- Abstract submitted to the 2004 SPIE Medical Imaging Conference.

CONCLUSIONS:

Base on our transmission ultrasound device and the micro-stepping motor we successfully generated the UCT images. The future work will be concentrated on two directions: "phantom design" and "filter design". We have tried several materials such as Jell-O and vegetable gelatin (extracted for seaweed) but failed. One reason that we select silicone to test is because we could make phantom in any shape, any size and even we could insert object in it. But the critical angle of the silicone surface is too small so that the ultrasound waves may significantly reflected without much transmission in several angles. We plan to modify the shape of the silicone phantom or find a better material to make the breast phantom. The Ram-Lak filter and the Shepp-Logan filter may not be perfect for the ultrasound attenuation profiles acquired by Imperium I100 chip. Therefore, we attempt to develop a better filter that could compensate for the ultrasound scattering and non-linearity of the sensor array (I100). In addition, we plan to use Imperium I300 or I400 chip to perform the study. These chips have a better dynamic range.

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